

Semi-Annual Report
(April, 1967)

NASA Grant NsG606

Kansas State University
Manhattan, Kansas

Submitted to: National Aeronautics and Space Administration

On: Analytic Studies in the Learning and
Memory of Skilled Performance

For the period: October 1, 1966 to March 31, 1967

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Date: April 24, 1967

Analytic Studies in the Learning and Memory of Skilled Performance

This is the sixth semiannual report of progress in the research conducted under NASA Grant NsG606. This Grant is technically monitored by Mr. Robert Randle of the Biotechnical Division of the Ames Research Center. The period covered by this report constitutes the final period of the original Grant and would normally require a final report at this time. However, since an extension of six months in the period of performance has been granted by the NASA Office of Grants and Research Contracts, the final report will be deferred until October, 1967.

Summary of Work for the Period Covered by this Report

During the period from October 1, 1966, to March 30, 1967, three pilot studies and two complete experiments, involving a total of over 165 subjects and nearly 400 hours of data collection, were completed; three reports have appeared in professional journals (Noble, Trumbo and Fowler, 1967; Trumbo, Noble and Swink, 1967; Noble and Trumbo, 1967); two additional papers are in press (Swink, Trumbo and Noble, in press; Trumbo, Noble and Quigley, in press); and another paper has been accepted for presentation at the Midwestern Psychological Association Meetings in Chicago, May 5, 1967. An additional body of data was collected specifically for computer analyses being conducted by the Conductron-Missouri Corporation. During the period of this report data

analyses were completed by Conduction on two earlier experiments and, at present, they are in the process of analyzing the data referred to above as well as data from four complete experiments. These analyses will be completed shortly and should permit a thorough evaluation of the performance indicants thereby obtained. Preparation of the data for analyses by Conduction, including logging and editing of data stored on magnetic tapes, has been a major clerical task during the period of this report.

Experimentation

Data were obtained during October and November on pilot studies and on the first completed study involving dual motor tasks. It will be recalled from the previous semiannual report (October 1966) that a series of experiments involving a primary (tracking) task and a secondary (verbal) task had indicated inter-task interference in the dual-task situations which appeared to be a function of the decision-making (response-selection) requirements of the second task when an overt verbal response was required. That is, it appeared that secondary task information could be processed (learned) simultaneously with and without interfering in performance on the primary tracking task, so long as the operator did not have to select and produce a second, overt response.

The purpose of the study conducted in October-November was to determine whether the same generalizations about human dual-task performance would hold when the second task was another motor, rather than a verbal task. In addition, the experiment was designed to evaluate the effects of the temporal phasing of the inputs from the two tasks on the degree of primary task interference. With respect to this latter variable, it was assumed that the temporal relation between the onset of critical events (i.e., the target steps) in the tracking (primary) task and the onset of events in the secondary task would be an important determiner of the amount of interference in tracking performance resulting from the secondary task.

Pilot studies

Several pilot studies were attempted before an experiment could be adequately instrumented for secondary task requirements. All pilot studies and the completed experiment had certain features in common. The primary task in every case was a pursuit tracking task with an irregular square-wave input at one step per second. The spatial pattern of steps was twelve targets long with the pattern completely fixed and repeated four times per trial. The secondary task input was a series of audible relay clicks to each of which the operator was to respond "as quickly as possible" by pressing a push-button mounted on a panel which served as a lateral

forearm rest for his left arm. Five buttons were located on the panel so as to fall comfortably one under each finger of the left hand. Thus, the operators' tasks were (1) to track the irregular square-wave input using a positional control, pivoted at the elbow of the right arm, and, simultaneously, to respond to the auditory clicks with a button-pressing response, using the fingers of the left hand.

In the first pilot study, the secondary task signals ("clicks") were programmed at a two-second rate. Experimental conditions included two response conditions and two intra-task phasing conditions in a 2 x 2 design with four subjects per condition. Response conditions were "single button" versus "five-button," or no selection versus response selection conditions. In the no-selection task the subjects were instructed to respond as quickly as possible to the click, using only the button under the index finger, while, in the response-selection condition, subjects were told to respond with any of the five buttons, in any order, but to use all the buttons in the course of a trial. (This condition was analogous to the "free response" of the previous secondary verbal task: see Trumbo, Noble and Swink, 1967). Phasing conditions were (1) zero delay, and (2) .5 sec. delay between the onset of the one-second steps of the tracking input and the clicks of the secondary task. Thus, in one case the click occurred simultaneously with every second displacement of

the target (zero delay), while in the other case the click occurred .5 sec. after every second displacement of the target.

The results for the primary task were clearcut: The response-selection (five button) requirement of the secondary task resulted in greater deterioration of tracking performance than the no-selection (single button) task. This finding was consistent with the results from our prior studies which involved the verbal secondary task. However, the phasing of primary and secondary tasks had no apparent effect on tracking performance: zero delay and .5 sec. delay conditions did not differ.

A limitation of this first pilot study was that the secondary task scores (summed response time for all clicks for a 48 sec. Trial) were equivocal because the apparatus and scoring did not allow us to identify "failures to respond." These failures had indeterminant effects on summed response time with the result that performance on the secondary task could not be accurately evaluated.

The second pilot study involved 24 subjects in the same conditions as were used in the first study, with one modification: the onset of the secondary task click was accompanied by the onset of a small light located immediately in front of the response buttons of the left hand. The light, which remained on until a response was made, was included to reduce or prevent the no-response problem found in the first study. However, the results

showed greater tracking error for the single-button condition in this study than in the first, essentially washing out the difference between single and multiple response conditions. That is, the difference due to the response requirements of the second task nearly disappeared, apparently because there was greater interference for the subjects with the single response button than found in the first study. Apparently, the light, rather than serving as an added cue to facilitate secondary task responding, became a distractor from the primary task.

The third pilot study saw the removal of the secondary task light cue and the introduction of a variable interstimulus interval between the secondary task clicks. Rather than a fixed two second interval, clicks were presented at two, three and four second intervals with a mean interval of three seconds. Twenty-four subjects were run, six each, in the four conditions of the previous studies, plus two conditions wherein the delay was .75 sec. between target displacement and click, one with single button, the other with five button secondary response requirements.

Again, in this third pilot study, the phasing of secondary and primary tasks had no effect on the amount of interference with primary task performance.

Finally, in the fourth study (the first completed experiment), the design was modified from that of the earlier pilot studies. It was speculated that failure to find tracking performance differences due to the phasing of primary and secondary task inputs might have been the result of inadequate learning of the tracking task by all subjects. Since in each of the pilot studies the secondary task was introduced from the beginning of training, it was conceivable that its interference, regardless of response selection conditions, was sufficient to mask difference due to temporal phasing of the tasks. Therefore, in the fourth study, subjects were first trained for 35 forty-eight second trials on the tracking task alone, before the secondary task conditions were introduced.

All subjects were trained on the same fixed-pattern square-wave tracking input used in the pilot studies. Secondary task conditions constituted a 2×4 design with two response conditions (single button vs. five-choice buttons) and four primary-secondary phasing conditions (.25, .50, .75 and zero delay). Sixty-four subjects were assigned, eight each, to these eight conditions and were run for 95 trials in five consecutive daily sessions. Secondary task conditions were present from trial 36 through trial 80.

The major results of this study are presented in Table I which summarizes an analysis of variance for the integrated

error scores obtained on the primary task for the two sessions when the secondary task conditions were presented.

Table 1. Summary of Analysis of Variance for the Secondary Motor task study.

<u>Source</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Ss	63	45.90		
Phasing Intervals (I)	3	3.32	1.11	1.73 N.S.
Response Conditions (R)	1	5.02	5.02	7.84 **
I x R	3	1.65	.55	----
error (between)	56	35.91	.64	
Within Ss	64	20.30		
Days	1	14.13	14.13	14.57 **
D x I	3	.24	.08	----
D x R	1	.08	.08	----
D x I x R	3	.41	.14	----
error (within)	56	5.44	.97	
Total	128	66.20		

These results indicate that the response requirements of the secondary task were a significant source of variance in tracking performance scores (integrated error), but that no significant effects could be attributed to the phase relations between the two tasks. The significant "Days" effect substantiated the evidence that subjects did improve their tracking performance

under secondary task conditions: In fact, subjects in single-response conditions nearly overcame the interference effects of the secondary task by the end of the second day.

Thus, as with the earlier studies involving verbal secondary tasks, this study supported the conclusion that the response-selection requirements of a secondary task are important determinants of the level of interference with the primary task. The significance of the present study is in the demonstration of the effect when the secondary task is a motor, rather than a verbal task, thus, increasing the generality of the finding regarding response-selection.

Primary efforts during December and January were on the preparation of data previously collected (including that from the study just described) for processing by Conductron-Missouri, Inc. As indicated earlier, additional data were collected specifically for evaluation of computer analyses by Conductron. Magnetic tapes were edited and paper tape logs were prepared for all recorded data to be analyzed.

During February and March, data collection was completed for the second study of the subject six-month period. This study involved 32 subjects, eight each, in four experimental conditions. The experiment was a sequel to the two sequential probability studies reported earlier (Quigley, Trumbo and Noble, 1966; Trumbo, Noble and Quigley, in press). It will be recalled that

in these prior experiments, response strategies were compared for various digram probabilities within the sequence of target events. Thus, for example, from target position A, the target might move either to B or C with, say, .90 and .10 probabilities, respectively. For alternative conditions, the probabilities might be .80 and .20, .70 and .30, etc., but in each case there were two alternatives from each target position.

In the present study, the purpose was to compare response strategies when the higher of two probabilities was the same in two experimental conditions, but the low probability was, in one case, assigned to one alternative, and in the other case, to two alternatives; for example target position A might be followed by position B ($p = .70$) or C ($p = .30$) in one condition, or by position B ($p = .70$) or C ($p = .15$) or D ($p = .15$) in the other condition. The basic question was whether or not the same strategies observed in the prior studies (Trumbo, Noble and Quigley, in press) would be modified by changes in the distributions of the low probability over one or more alternatives.

The design was again a 2 x 2 factorial with two values associated with the high probability targets (.70 and .85) and two conditions with respect to the distribution of the residual low probabilities (one vs. two low p alternatives). Thus, for each of the four conditions, each target position was followed by one

high p event (.70 or .85) and by one (.30 or .15) or by two (.15, .15 or .075, .075) low p alternatives. Eight subjects were run for forty 48 sec. trials for each of the four conditions with trials divided over two daily sessions. The basic pattern of alternatives was the same for all conditions; that is, the high and low p sequential alternatives were the same for both two alternative and both three alternative groups. Furthermore, the pattern was designed so that the position of low p event for the single-low p alternative condition fell midway between the positions of the two low p alternatives in the two-low p conditions. The target pattern consisted simply of two problems, one requiring a choice of direction, the second requiring a choice of amplitude of response, only. Thus, position "C" might be followed by position "A" or position "F" (directional choice, (one low p alternative), or by "A" or "D" or "G" (directional choice, two low p alternatives). The amplitude choice problem would then occur: "A" might be followed by "B" or "D" (one low p event) or by "B," "C" or "E" (two low p events). These two decision problems (one directional, one amplitude choice) were repeated throughout all trials.

The data from this experiment are currently being analyzed; however, some partial results indicate (1) a "matching" strategy is developed in anticipating the direction of target displacements

in directional choice problems. That is, subjects tend to anticipate by moving the control to the left or right proportionately with the probabilities that the target will go left or right. Thus, when the target goes to the left 70 percent of the time, subjects made anticipatory responses to the left 75 percent of the time. This was true when there was a single low probability alternative in the opposite direction (.70/.30 condition). However, when there were two low p alternatives (.70/.15/.15) subjects came much closer to maximizing, that is, always going to the high p alternative (88% of anticipatory responses).

The "matching" behavior is quite consistent with our previous findings (Quigley, Trumbo and Noble, 1966) but the shift toward maximizing when the low p total is distributed over two, rather than one, alternative event is a unique finding in this study. Analysis of the complete data for the study will determine the reliability of these trends and will indicate strategies with respect to amplitude choices, as well.

Development of Performance Indexes and Computer Methods

From the analyses thus far completed by Conduccion we obtained 23 performance indices. These indices are being evaluated by two methods: (1) where hand-scored data are available, comparisons are being made with indexes which, on a priori grounds, should relate to the hand scored values. For example, hand-scored

"lead-lag" indicants should correlate with "average phase angle" computer outputs. The results so far evaluated indicate correlations between .83 and .92 between these indicants, thus providing concurrent validation information for the computer scores. (2) The 23 performance indicants are being intercorrelated at the Kansas State University Computer Center. The intercorrelation matrices will be examined to evaluate the uniqueness and the redundancy of the various indicants. A possible further step will be to factor analyze the indicants to determine factor structure and factor loadings.

The purpose of these two follow-up analyses of the computer indicants is to evaluate their meaning and their sensitivity to task differences, practice levels, and performance levels in the experiments from which the data were obtained. Insensitive measures, or measures which do not have clear referents in human performance will be discarded. Meanwhile, those measures of demonstrated sensitivity will be compared and tested further to clarify their significance for information processing and skilled performance.

Research Projected for the
Extended Performance Period

During the extended performance period of the Grant (April 1, 1967 to September 30, 1967) data will be collected on two studies concerned primarily with the temporal aspect of response organization. It has long been recognized that anticipatory timing is a critical aspect of human performance. The studies conducted in our laboratory over the past five years have clearly supported this conclusion. The two studies, which are presently in the planning and pilot data-collection stages, are designed to provide evidence on the human operator's ability to develop, retain, and transfer temporal patterns of responding, and to evaluate certain task parameters as they affect this ability. Each of these studies will probably involve two or more separate experiments, and it is anticipated that the net outcome will be a significant contribution to our understanding of timing in human skill performance. Details of these experiments are not complete at the present time; however, both studies will be concerned with (1) optimal timing, as determined by input rate, and as measured both by accuracy in synchronizing responses with anticipated target events, and the variability of responses, i.e., RMS error, with respect to timing; (2) the role of various cues, for example, augmenting auditory cues, in timing accuracy;

(3) the process of adapting to subtle changes in response rate requirements; (4) the processing of information about the temporal aspect of the task, both with respect to fixed patterns and probabilistic patterns of temporal events, and (5) the response strategies developed with respect to correcting for temporal errors, (or phase errors) in performance. That is, the questions of continuous versus discrete corrective processes, and, assuming discrete corrections, the frequency of correction, will be examined. More detailed statements of the studies will be submitted as an interim report at a later date.

In addition to these experiments on timing performance, it is anticipated that one or more experiments on response organization as a function of sequential probability conditions and/or secondary task conditions will be completed. These two areas of research have, we feel, produced the greatest payoff in information about human performance, information-processing and decision-making of any we have completed. While specific experiments have not been designed, we fully anticipate that one or two will be completed in these areas before the conclusion of the extended performance period for NASA Grant NsG606.

Personnel

Listed below are the names and position titles of all personnel who have been associated with NASA Grant Nsg 606 during the period October 1, 1966 to March 31, 1967.

Name	Title	Total time on project	Time charge to NASA
Noble, Merrill E.	Co-Investigator (Faculty-Psych.)	.6 mo.	--
Trumbo, Don A.	Co-Investigator (Faculty-Psych.)	--	--
Swink, Jay R.	Research Asst. (GRA-Psych.)	3.0 mo.	.5 time (3 mo. to NASA)
Penick, Benson	Research Asst. (GRA-Psych.)	3.0 mo.	.4 time (2.4 mo. to NASA)
Quigley, Carolyn	Research Asst. (RA-Psych.)	3.0 mo.	.5 time (3 mo. to NASA)
Bentrup, Dale	Research Asst. (E.E.-GRA-Psych.)	3.0 mo.	.4 time (2.4 mo. to NASA)
Corke, Verna	Clerical-Research (Kans. Civil Service)	6.0 mo.	full time (5.6 mo. to NASA)
Reling, Clorene	Account Clerk	1.3 mo.	part time (1.3 mo. to NASA)
Nickerson, Charlotte & Tessendorf, Carolyn	Clerical	.6 mo.	--

Financial Review

The official financial report will be submitted through the Comptroller's Office of Kansas State University as soon as it is completed.

Conferences

Drs. Trumbo and Noble attended the Annual Meetings of the Psychonomic Society in St. Louis, Missouri, in October, 1966.

Dr. Lowell Schipper visited Kansas State University as a Consultant to NASA Grant NsG 606 in December, 1966.

Dr. Trumbo and Engineering Assistant Dale Bentrup visited Conductron-Missouri in St. Charles, Missouri in January, 1967, to consult with the engineers who are providing computer analyses for our data.

Dr. Noble attended the NASA-USC Conference on Manual Controls in Los Angeles, California, in March, 1967.